



# Technology Focus: Data Acquisition

## Software Tool Integrating Data Flow Diagrams and Petri Nets

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Data Flow Diagram – Petri Net (DFPN) is a software tool for analyzing other software to be developed. The full name of this program reflects its design, which combines the benefit of data-flow diagrams (which are typically favored by software analysts) with the power and precision of Petri-net models, without requiring specialized Petri-net training. (A Petri net is a particular type of directed graph, a description of which would exceed the scope of this article.)

DFPN assists a software analyst in drawing and specifying a data-flow diagram, then translates the diagram into a Petri net, then enables graphical tracing of execution paths through the Petri net for verification, by the end user, of the properties of the software to be developed. In comparison with prior means of verifying the properties of software to be developed, DFPN makes verification by the end user more nearly certain, thereby making it easier to

identify and correct misconceptions earlier in the development process, when correction is less expensive. After the verification by the end user, DFPN generates a printable system specification in the form of descriptions of processes and data.

*This work was done by Carroll Thronesbery of S&K Technologies and Madjid Tavana of LaSalle University for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23242*

## Adaptive Nulling for Interferometric Detection of Planets

Deep nulls would be obtained despite optical imperfections.

NASA's Jet Propulsion Laboratory, Pasadena, California

An adaptive-nulling method has been proposed to augment the nulling-optical-interferometry method of detection of Earth-like planets around distant stars. The method is intended to reduce the cost of building and aligning the highly precise optical components and assemblies needed for nulling.

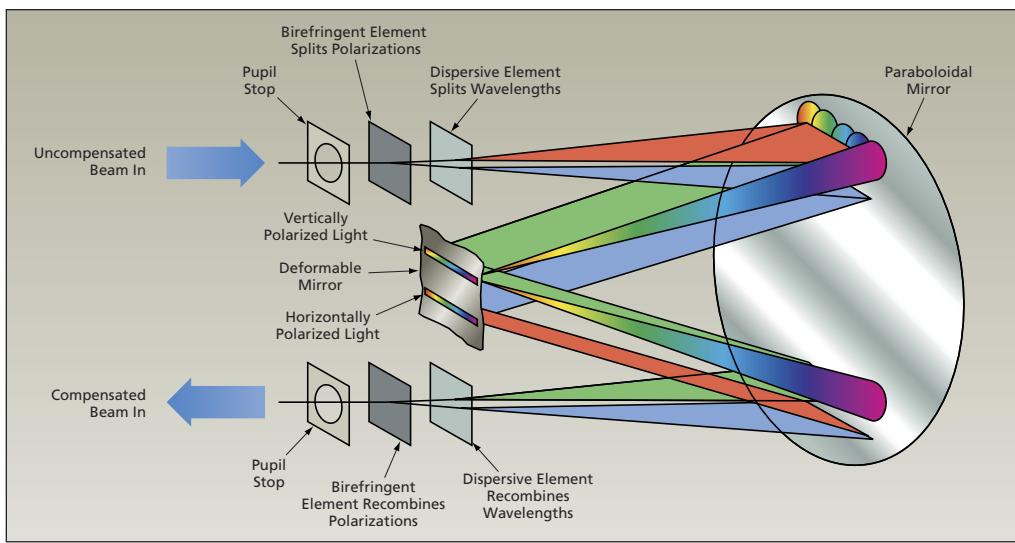
Typically, at the mid-infrared wavelengths used for detecting planets orbiting distant stars, a star is millions of times brighter than an Earth-sized planet. In order to directly detect the light from the

planet, it is necessary to remove most of the light coming from the star. Nulling interferometry is one way to suppress the light from the star without appreciably suppressing the light from the planet.

In nulling interferometry in its simplest form, one uses two nominally identical telescopes aimed in the same direction and separated laterally by a suitable distance. The light collected by the two telescopes is processed through optical trains and combined on a detector. The optical trains are designed such that the

electric fields produced by an on-axis source (the star) are in anti-phase at the detector while the electric fields from the planet, which is slightly off-axis, combine in phase, so that the contrast ratio between the star and the planet is greatly decreased. If the electric fields from the star are exactly equal in amplitude and opposite in phase, then the star is effectively "nulled out."

Nulling is effective only if it is complete in the sense that it occurs simultaneously in both polarization states and at all wavelengths of interest. The need to ensure complete nulling translates to extremely tight demands upon the design and fabrication of the complex optical trains: The two telescopes must be highly symmetric, the reflectivities of the many mirrors in the telescopes and other optics must be carefully tailored, the optical coatings must be extremely uniform, sources of contamination must be minimized, optical surfaces must be nearly ideal, and alignments must be extremely precise. Satisfaction of all of these requirements entails substantial cost.



**Light Would Be Decomposed** into wavelength and polarization components, the phases and amplitudes of which would be controlled by use of a deformable mirror. The components would then be recombined to obtain a compensated beam.

In the proposed method, a compensator would be inserted into each optical train, upstream of the location where the output beam from the two telescopes are combined. Each compensator would be an optical subsystem that would control the amplitude and phase of the electric field of the spatial mode that couples into the detector, and would do so independently at each wavelength for each of the two polarization states of the beam. The compensator would correct for the imperfections in the optical train and in the beam combiner, making it possible to obtain a deep null from an imperfect instrument.

In one conceptual compensator (see figure), the uncompensated beam from

the telescope would be split by a birefringent optical element into vertically and horizontally polarized components, which would be dispersed into wavelength components. The light of the various wavelength components would be focused by a paraboloidal mirror onto a deformable mirror, forming two bright lines, each corresponding to the dispersed spectrum for each polarization state. That is to say, each combination of polarization and wavelength would be focused to a different point on the mirror. The local piston displacement and local slope of the deformable mirror would be controlled to control the phase and amplitude, respectively. Then the light would be re-collimated by the paraboloidal mirror, the wavelength

components would be recombined by another dispersive optical element, and then the horizontal and vertical polarization components would be recombined by another birefringent element to produce a single, corrected output beam. The sensing of the amplitude and phase errors and the control of the deformable mirror would be effected by use of a combination of previously developed nulling and wavefront-sensing-and-control techniques. This approach has been successfully demonstrated in the laboratory, both at near-infrared and mid-infrared wavelengths.

*This work was done by Oliver P. Lay and Robert D. Peters of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-40152*

## Reducing the Volume of NASA Earth-Science Data

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A computer program reduces data generated by NASA Earth-science missions into representative clusters characterized by centroids and membership information, thereby reducing the large volume of data to a level more amenable to analysis. The program effects an autonomous data-reduction/clustering process to produce a representative distribution and joint relationships of the data, without assuming a specific type of distribution and relationship and without resorting to domain-specific knowledge about the data.

The program implements a combination of a data-reduction algorithm known as the entropy-constrained vector quantization (ECVQ) and an optimization algorithm known as the differential evolution (DE). The combination of algorithms generates the Pareto front of clustering solutions that presents the compromise between the quality of the reduced data and the degree of reduction.

Similar prior data-reduction computer programs utilize only a clustering algorithm, the parameters of which are tuned manually by users. In the present

program, autonomous optimization of the parameters by means of the DE supplants the manual tuning of the parameters. Thus, the program determines the best set of clustering solutions without human intervention.

*This program was written by Seungwon Lee, Amy J. Braverman, and Alexandre Guillaume of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-45583.*

## Reception of Multiple Telemetry Signals via One Dish Antenna

**Telemetry signals coming from slightly different directions can be separated.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A microwave aeronautical-telemetry receiver system includes an antenna comprising a seven-element planar array of receiving feed horns centered at the focal point of a paraboloidal dish reflector that is nominally aimed at a single aircraft or at multiple aircraft flying in formation. Through digital processing of the signals received by the seven feed horns, the system implements a method of enhanced cancellation of interference, such that it becomes possible to receive telemetry signals in the same frequency channel

simultaneously from either or both of two aircraft at slightly different angular positions within the field of view of the antenna, even in the presence of multipath propagation.

The present system is an advanced version of the system described in "Spatio-Temporal Equalizer for a Receiving-Antenna Feed Array" NPO-43077, *NASA Tech Briefs*, Vol. 34, No. 2 (February 2010), page 32. To recapitulate: The radio-frequency telemetry signals received by the seven elements of the array are digitized, converted to complex

baseband form, and sent to a spatio-temporal equalizer that consists mostly of a bank of seven adaptive finite-impulse-response (FIR) filters (one for each element in the array) plus a unit that sums the outputs of the filters. The combination of the spatial diversity of the feed-horn array and the temporal diversity of the filter bank affords better multipath-suppression performance than is achievable by means of temporal equalization alone. The FIR filter bank adapts itself in real time to enable reception of telemetry at a low bit error rate, even in the